227216

U.S. Department of Transportation
Office of the Secretary of Transportation

General Counsel

1200 New Jersey Avenue, S.E.
Washington, D.C. 20590

June 4, 2010

Ms. Cynthia Brown
Chief of the Section of Administration
Surface Transportation Board
395 E Street, S.W.
Washington, D.C. 20423

ENTERED
Office of Proceedings
JUN 4 2010
Part of
Public Record

Re: Finance Docket No. 35305

Dear Ms. Brown:

Enclosed herewith for filing in the above-referenced proceeding please find the Rebuttal Comments of the United States Department of Transportation. Please contact me if you have any questions.

Respectfully,

Paul Samuel Smith

PAUL SAMUEL SMITH
Senior Trial Attorney

(202) 366-9280

Enclosure

cc: All Parties of Record

Before the
Surface Transportation Board
Washington, D.C.

ARKANSAS ELECTRIC COOPERATIVE CORPORATION -- PETITION FOR DECLARATORY ORDER	)	F.D. No. 35305

Rebuttal Comments of the
United States Department of Transportation

Introduction

Previously in this proceeding the United States Department of Transportation ("DOT" or "Department") found that accumulating coal dust can undermine the integrity of the ballast underlying railroad track and thereby threaten safety and possible violations of Federal Railroad Administration ("FRA") regulations. DOT Reply Comments (filed April 30, 2008) at 2. The Department also took the preliminary position that (1) shippers of coal, like those of other freight, should generally be responsible for loading and securing their property so that it remains within the confines of rail cars during transportation, and (2) to be "reasonable" as required under federal law, the BNSF Railway Company ("BNSF") tariff rule at issue must be technically well-grounded and cost-effective at resolving the problem of coal dust emissions. [1] We noted that this position was subject to change in light of evidence and arguments presented by other parties. *Id.* at 8. The submissions of other parties have raised issues that do indeed call these views into question. Although DOT does not ultimately find them persuasive, they warrant additional discussion.

[1]/ DOT grounded this latter point in the need for the Surface Transportation Board ("STB" or "Board") to fulfill its statutory obligation to make "reasonableness" determinations. *Id.* at 6-7; 49 U.S.C. § 10702. The Administrative Procedure Act reinforces that duty through its demand that agency decisions be reasonable and supported by substantial evidence. 5 U.S.C. §§ 553 *et seq.*

Coal Dust and Safety

Most fundamentally, some parties continue to question whether coal dust is any more harmful than other matter found in ballast. Reply Evidence and Argument of Western Coal Traffic League, et al. ("WCTL Reply") at 13-16; Arkansas Electric Cooperative Corporation Reply Evidence and Argument ("AECC Reply") at 23-24. The consequences of coal dust are critical to this proceeding, for reasonableness entails a cost-benefit analysis in which the costs of a measure are supposed to be roughly commensurate with the benefits obtained thereby. DOT Reply Comments at 6-7 and cases cited therein. The less harmful coal dust is the less benefit there is to be gained from its removal, and the less reasonable would be a requirement imposing substantial burdens on shippers to remove it.

The Department does not agree that coal dust is no more harmful than any other matter commonly found in ballast on the Powder River Basin ("PRB") lines in question. FRA's experience confirms the record evidence that coal dust interferes with the stability of ballast to a much greater extent than other such materials. DOT's Volpe National Transportation Systems Center has conducted several studies on track buckling to evaluate track strength and stability limits, including the effects of ballast condition. These materials and the relevant literature on the subject confirm the particularly destructive qualities of coal dust on ballast. [2]

Ballast ideally consists of uniform, angular stone material (such as granite) that supports and surrounds railroad ties. It forms a layer in which the angular particles contact adjacent particles; these small contact points provide a high level of resilience. Rail traffic subjects the

---

[2]/ The pertinent pages of that literature are attached hereto. The Volpe studies are available at: http://www.volpe.dot.gov/sdd/pubs-buckle.html.

ballast to loading forces that compress the particles ever more closely and tightly together, enhancing their stability. Eventually, however, these forces break down the ballast, which often becomes the most common fouling agent by weight. Typical ballast fouling agents are ballast breakdown, blown or spilled debris, and other track materials.

The usual fouling material is a dust that can turn into a muddy slurry when moisture is present, which fills in the spaces between ballast particles. Whether moist or dry, the lubricating qualities of these fouling agents can allow the particles to slide past one another rather than to compress together and stability suffers. Further loading under these circumstances tends to force the ballast particles farther apart, ultimately threatening track geometry.

Coal dust has especially low strength compared to other common fouling agents (like granite or silt or clay) and absorbs water very well. Moreover, although fouling agents are commonly measured and compared by weight, the lower density of coal dust allows it to occupy a much greater space or volume among ballast particles than would the same weight of other agents. [3] The result is that coal dust accelerates the destabilization of ballast much more than other fouling materials and requires more immediate and/or more frequent corrective action.

There is certainly room for debate about the particular means employed by BNSF to measure coal dust emissions in the PRB and translate those measurements into quantitative standards. But there should be no meaningful doubt about the particularly pernicious effects of accumulated coal dust on rail ballast.

---

[3]/ The common density of broken coal ranges from 0.8-1.1 g/cc, while broken granite ranges from 2.64-2.75 g/cc and silt and clay range from 2.3-2.86 g/cc, meaning that the volume occupied by coal dust would be at least 2.4 times larger than an equal amount (by weight) of these other fouling agents. Volume, not weight, is thus the proper measure of coal dust and other contaminants where effects on ballast are concerned.

Responsibility for Coal Dust Emissions

Coal shippers deny responsibility for control of the dust that escapes from their shipments on several grounds. First, they assert that they have never been held responsible for such emissions, and indeed that legal precedent supports them; second, they point out that they follow railroad requirements with respect to the use of open coal cars and loading techniques; and third, they emphasize that the coal dust escapes while their traffic is within the exclusive control of the railroads. WCTL Reply at 22-24; AECC Reply at 3-6; Reply Comments of American Public Power Association, Edison Electric Institute, and National Rural Electric Cooperative Association ("APPA Reply") at 3-4, 14. None of these contentions prompts any change in the Department's position.

First, the fact that railroads have not previously attempted to use tariff rules to hold shippers responsible amounts to inertia, not a reason to hold BNSF's current rule unreasonable. Changed circumstances support a changed response. DOT Reply Comments at 5. Second, the single legal precedent cited by shippers is inapposite. The fact that a state county court decided shippers were not liable at common law for trespass or nuisance on account of coal dust emissions does not dictate the course of the Board's regulation of interstate common carriers under applicable federal law. *See Akron, Canton and Youngstown Railway Co. v. ICC*, 611 F.2d 1162, 1166 (6th Cir. 1979); *Maynard v. CSX Transportation, Inc.*, 360 F.Supp.2d 836, 839-43 (E.D.Ky. 2004) (state common law claims do not prevail over federal oversight) 611 F.2d 1162, 1166. Third, virtually all rail traffic of which DOT is aware (other than nuclear fuel) is under the exclusive control of railroads while being transported. A certain amount of rocking motions, of starts and stops, and of other operation-related movements is inherent in rail transportation. Yet that reality has never translated into a transfer of responsibility for securing any other kind of freight from shippers to carriers, and it offers no reason for doing so here.

The coal shippers also contend that because they use open coal cars and load those cars according to carrier demands, it would be unreasonable (or at least unfair) to hold them solely responsible for spillage that results. APPA Reply at 3-4; AECC Reply at 5, note 2; *also* Opening Statement of TUCO INC. at 3-4. The record does not definitively establish that these requirements are in fact unilaterally imposed or whether there is any precedent going to their reasonableness. [4] But the record *does* contain clear suggestions that these requirements proceed either from a joint railroad-shipper process conducted via the Association of American Railroads (APPA Reply at 4), from contractual provisions (TUCO INC. at 4), or from the pursuit of maximum efficiency (AECC Reply at 5, note 2).

The first of these offers, as the shippers attest, a collaborative means for all interested parties to address the implications of these requirements for coal dust emissions and the best method of addressing them. DOT fully supports a cooperative endeavor by railroads, shippers, and mine owners to resolve the problem at hand. Such alternatives are properly preferred by the Board to regulatory action as a general matter. [5] The other possible sources of car type and loading requirements, however, counsel caution. Contracts are beyond the agency's reach and represent bargains agreed upon by the parties thereto; efficiency lowers costs and redounds to the benefit of all concerned.

---

[4]/ Assuming *arguendo* that railroads do in fact literally impose such requirements, particularly in the face of shipper opposition, fairness (at least) might favor a shifting of or sharing in responsibility for the coal dust emissions that inevitably follow in the real-world motions of rail carriage.

[5]/ *E.g.*, concern about coal dust emissions in Australia led railroads, shippers, mines, and government agencies to agree upon multiple mitigation steps, including surfactant spraying and modifications to coal loading and profiling techniques. *See* http://www.qrnetwork.com.au/About-us/Environmental-policies/Coal-loss-management.aspx .

Reasonableness and Cost-Effectiveness

BNSF has made two points to which DOT would like to respond. First, the railroad claims that a comparative cost analysis is not appropriate in determining the reasonableness of its tariff rule. BNSF Reply Evidence and Argument ("BNSF Reply") at 15. The Department disagrees. BNSF relies upon common law trespass precedent, but that is as inapposite for this purpose as it is for relieving shippers of responsibility for securing their property in interstate commerce. *Akron, Canton & Youngstown Rwy, supra*; *see also* DOT Reply Comments at 6-7.

Second, BNSF contends that the costs of service disruptions and capacity constraints brought about by additional maintenance of way should be taken into account in any comparisons of the costs of alternative measures for dealing with coal dust emissions. BNSF Reply at 15-16. [6] DOT agrees because those costs are real and clearly tied to emissions. *See North American Freight Car Ass'n. v. BNSF Railway Co., STB Docket No. 42060 (Sub-No. 1)* at 6. But the Board should consider whether coal shippers are already bearing those costs.

The PRB lines on which the coal dust falls and the shippers whose traffic would be most affected by emission-related capacity constraints would seem to be clearly identifiable in this proceeding (*e.g.*, the Joint Line), relatively isolated from other parts of UP or BNSF rail networks and from other freight and its shippers. Therefore these carriers should be able to provide information about the impact those maintenance activities have had on rail capacity for those segments (and, going forward, whether additional capital investment might be necessary at some point due to those activities.) Moreover, the additional maintenance that coal dust

---

[6]/ BNSF ultimately asserts that a valid cost comparison would show surfactant spraying by shippers to be less costly overall than the full costs of additional maintenance undertaken by railroads. *Id.* at 18-19.

emissions have required in recent years has presumably already been having a detrimental effect on capacity in the PRB region, the costs of which (in extended cycle times, increased stockpiling of coal, etc.) coal shippers have also presumably and properly had to absorb.

If so, what would remain to be determined is the most cost-effective -- i.e., reasonable -- method of addressing the problem of coal dust emissions. If additional maintenance of way is the lowest cost option, shippers ought to pay for its direct costs and continue to bear the brunt of the resultant but indirect capacity constraints. If, on the other hand, surfactant spraying is less expensive, then shippers should pay for that and constraint-related costs would disappear with the (no-longer-necessary) additional maintenance that caused them.

Conclusion

Coal dust is a particularly harmful ballast contaminant that requires frequent remedial action. Coal shippers should be held accountable for loading their freight so that it remains within the cars that transport it, and should bear the cost of the most efficient corrective measures when coal dust escapes. The Department encourages railroads and shippers to work cooperatively to identify and implement those measures.

Respectfully submitted,

ROBERT S. RIVKIN
General Counsel

June 4, 2010

ATTACHMENT

RAILROAD ENGINEERING

Second Edition

WILLIAM W. HAY, Mgt. E., M.S., Ph.D.

Professor Emeritus of Railway Civil Engineering
University of Illinois, Urbana, Illinois

A Wiley-Interscience Publication
JOHN WILEY & SONS
New York Chichester Brisbane Toronto Singapore

CHAPTER

21

Ballast

The ballast section is a logical extension of the subgrade, a placing of the most select materials in the zone of maximum stress concentration.

BALLAST FUNCTIONS AND TYPES

The railroad term *ballast* is possibly a carry-over from the use in early track of sand and gravel that had been carried as ballast in ships. In railroad usage it refers to permeable, granular materials such as sand, gravel, crushed rock or slag, chat, cinders, and so on placed around and under the ties to promote track stability (Figure 21.1).

1. Purposes of the Ballast Section

In promoting track stability, ballast performs several well-defined functions.

1. The load of the track and railroad traffic is transmitted to and distributely uniformly over the subgrade with diminished unit pressure. Without ballast, the ties would sink unevenly into the subgrade under the pressure of concentrated loads.

2. The track is anchored in place against lateral, vertical, and longitudinal movement. Irregular-shaped ballast particles interlock with the ties and with each other to resist the disturbing forces of dynamic loads.

3. Moisture is drained quickly away from the track and not allowed to accumulate around rails and ties. The shape of the section and the porous free-draining properties of ballast materials provide immediate drainage.

Prepared Gravel. Pit run gravel displays varying qualities. By washing and screening out excessively fine and silty materials, a ballast of uniform quality and characteristics is obtained. Large pieces are crushed to proper size, and deleterious substances are removed. Sufficient fines are included to bed and secure the larger particles. Gravel lacks the strength and durability of stone and cannot ordinarily be cleaned. It is, however, easy to work with, frequently available, and relatively inexpensive. Gravel is found and used extensively throughout the Midwest and Northwest.

Pit Run Gravel. Some roads have access to gravel pits producing a material already reasonably uniform in quality and free from deleterious substances. Many miles of high-speed, mainline railroad have thus been ballasted at a minimum cost.

Chat. Chat is the tailings or refuse from zinc, lead, and silver mines and consists of small rock particles, including bits of ore. Although lacking the strength, durability, and cleanability of rocks, chat possesses these qualities to a reasonable degree, is the most easily worked of any main line ballast, and in certain mining localities is cheap and readily available.

Cinders. Cinders are a cheap and well-draining material. They lack compressive strength and will in time pulverize and harden. Cinders are the poorest for workability according to AREA tests. Lack of cleanability is in part compensated for by cheapness, which permits frequent renewals of the material. Cinders are suitable for yards and sidings, light-traffic branch lines, and may also be used as subballast and on main lines where unstable subsoils require frequent ballast applications to maintain the grade. Since diesel locomotives have replaced steam locomotives, cinders are not as available as in the past. A reduction in rail section by corrosive chemical action may result from cinders in contact with the rail.

Chert. Chert is a compact, flintlike, siliceous rock formed of microgranular silica of organic or precipitated origin. Found mostly in the West, chert exhibits qualities similar to chat.

Burnt Clay. Use has been made of burnt clay, particularly in the Southwest. It is formed by burning clay in beehivelike mounds and crushing it to a $\frac{3}{4}$–$1\frac{1}{2}$ in. size. It lacks strength and durability and has a high rate of moisture absorption. It is no longer used.

Sand. Sand can be used in the same locations as cinders. It lacks stability, particularly if the particles are rounded or possess excess moisture, and will blow and drift in windy areas. Its use is largely limited to secondary lines in seacoast areas.

Other Materials. The burnt tailings of coal mines, seashells, and even soil have been used in emergencies when other materials were not available or when the track under construction was temporary and subject to little use and light loadings.

Many questions remain as to the characteristics and in-track behavior that make these and other possible materials suitable or unsuitable for various types of ballast service.

3. Ballast-Subgrade System Review

In Chapter 15 all procedures, including an example based on Talbot's studies, indicated decreasing pressures in the ballast and subgrade with increasing depth below the ties. Stability requires that the tie load pressure be distributed or reduced in magnitude to within the bearing capacity of the subgrade soils. The usual medium for affecting this distribution is the ballast section.

Talbot's equation gives the pressure beneath the centerline of tie under the rail, p_c, as a function of unit pressure over the bearing area of the tie and of the depth h below that bearing surface, that is,

$$p_c = \frac{16.8p_a}{h^{1.25}} \tag{21.1}$$

If the tie pressure p_a (in pounds per square inch) and the bearing capacity of the subgrade, set equal to p_c, are known, the minimum depth h (in inches) for stability is

$$h = \left(\frac{16.8p_a}{p_c}\right)^{4/5} \tag{21.2}$$

The average bearing capacity of a normally firm subgrade soil is often taken as 20 psi and a maximum desirable unit tie pressure as 65 psi, especially for ballast of less than top quality [1]. For concrete ties a p_a value of 85 psi is allowed [1, p. 10-1-7]. Using the values of 20 and 65 psi in the foregoing equation, (21.2), a minimum desirable depth of ballast of 24.5 in. is indicated. If the 85-psi value with concrete ties is used, the depth becomes 30.4 in. The actual value of p_a is, in addition to tie width and spacing, a function of the total loaded car weight and speed. Depth of ballast is therefore, in part, a function of traffic loading.

Talbot's reports and later studies by Salem established the pressures in ballast at various depths as a percentage of the unit tie-bearing pres-

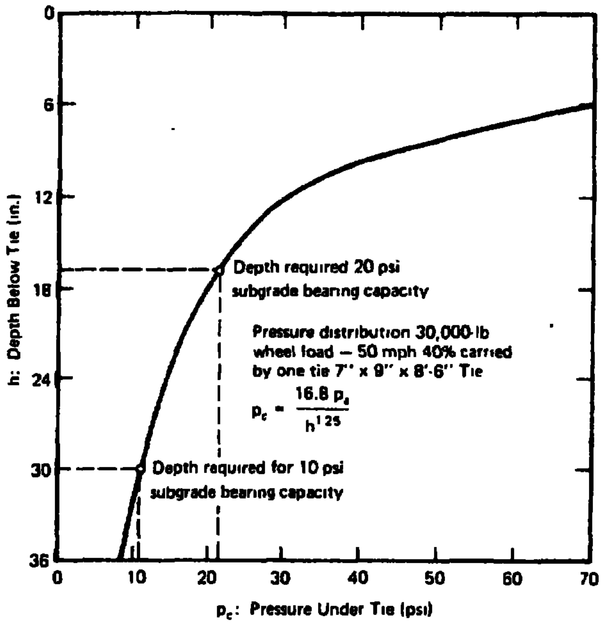

Figure 21.2. Pressure distribution versus depth.

sure p_a [2]. Talbot's charts (Figure 15.14) indicate uniformity of pressure occurring at a depth approximately equal to the center-to-center spacing of the ties (Figure 21.2). Such uniform distribution contributes uniformity to any settlement that occurs in track and ballast. The charts also give a method for establishing the required ballast depth to reduce tie pressures to within the bearing capacity of the subgrade. *Following sections will show a close relation between subgrade soil support and ballast section design and stability.*

The normally firm soil of 20-psi capacity is by no means the rule. Subgrade soils of 15, 10, or even 5 psi or less are not uncommon. Ballast depth must be adjusted in terms of a particular soil and anticipated loads (Figure 21.2). Further, the same soil may have different bearing capabilities at various times, depending on the moisture content and incidence of a freeze–thaw cycle. A factor of safety for the design of ballast depth would not be inappropriate.

Pressure distribution is generally not dependent on the kind of material. The upper 10 in. of a required 24-in. depth could be of top quality, the remaining 14 in. of lesser quality, forming a subballast. A filter blanket could serve as part of the subballast. Use has been made of a lime or cement-stabilized layer on atop of the subgrade in lieu of subballast. Geotextile fabrics as a substitute for ballast depth are not presently recommended here.

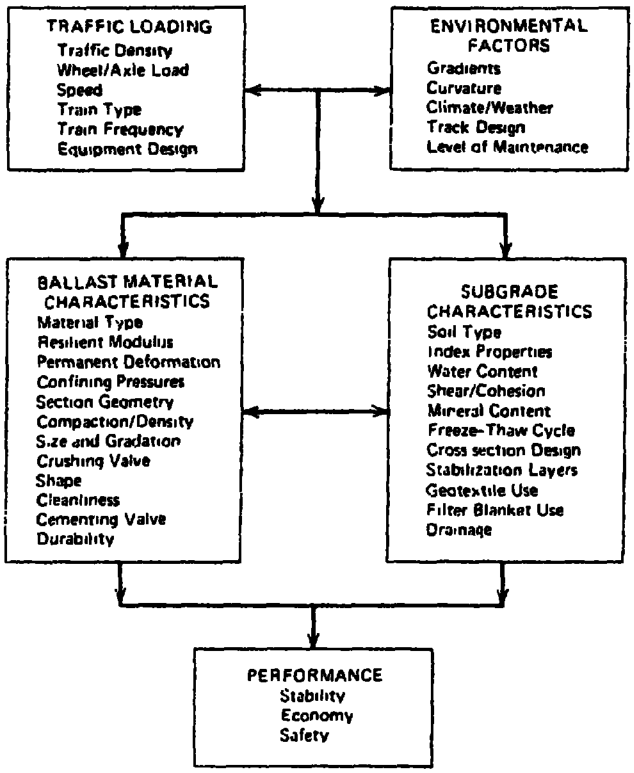

Figure 21.3. Traffic loading–support systems relation.

The Talbot-Salem methods of analysis make use of composite, lumped parameters. The support system is, however, a layered system in which each element or layer–subgrade, subballast, ballast–have their individual functions and characteristics. Even a layer of new ballast upon a layer of old ballast will be different from the old. Figure 21.3 shows the interrelation between ballast, subgrade, and traffic in support system design.

4. Effects of Ballast Inadequacy

Insufficient depth of ballast overloads the subgrade and increases the pore water pressures, thereby weakening the soil still further. There has been insufficient pressure distribution. Subgrade materials churn and infiltrate the ballast to form muddy track. Ballast particles penetrate the subgrade to form water pockets. In the worst situations subgrade soils squeeze upward at the toe of the ballast section or around the ties, and the track pumps and sinks.

Poor-quality ballast abrades to form muddy track and pumping joints. Abrasive dust and subgrade intrusion make a bad situation worse. Frost heaving may become pronounced. Abrasive dust from soft limestones and from slags with a high calcium content cement to form impermeable, inelastic masses that provide uneven support and impede drainage, tamping, cleaning, and undercutting. Surface and line are difficult to hold with concrete ties; a high-quality hard, stable material is required. Ballast must be especially stable under CWR.

Inadequate ballast quality or amount contributes to a rapid deterioration of surface and line, to shorter maintenance cycles and/or slow orders, and to accelerated wear on ties, rails, and fastenings, that is, to increased maintenance and train operating costs.

BALLAST CHARACTERISTICS

Behaviorial characteristics of a ballast material determine how well it will satisfy its functional requirements and affect its usefulness and economy as a material and the geometric design of the ballast section. Those characteristics must be known to permit a proper selection of material that gives overall economy. Two kinds of behavior are important: (1) the short-term elastic response and (2) the long-term permanent deformation and degradation.

5. Elastic Response

Resilience or elasticity is the ability of a material to return to its original shape or position after an applied load has been removed. It is the ability of the track to return to proper surface and line after being slightly deformed by the vertical and lateral forces of a passing train. Note, however, in Figure 21.4 that even with elastic response some small amount of permanent deformation occurs.

The AREA recommends that rail deflection, including ballast and subgrade, should not exceed 0.25 in. for good-quality track, to minimize such permanent deformation, and reduce wear on track components. Federal Railroad Administration (FRA) safety standards set maximum deflections in greater amounts for various speeds based on safety considerations. But the ability is lacking to design a combination of ballast material and geometric cross section to restrain geometric changes beyond a certain amount and for a stated time interval. Some of the factors are known qualitatively by experience, but there are no quantitative evaluations or specifications for track of a given life or maintenance cycle, that is, no performance specifications.

Recent studies by Thompson and his associates have identified

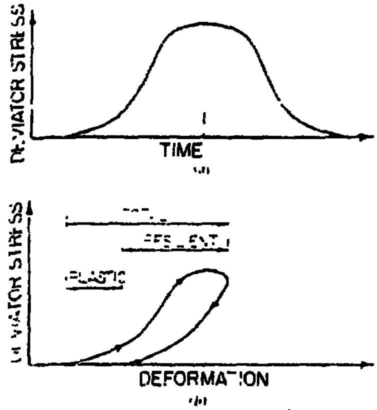

Figure 21.4. Plastic and resilient deformation.

significant factors that affect elastic response and have shown how these are interrelated and, to a degree, quantified [3]. Using triaxial testing procedures, the concept of the resilient modulus, used in describing the response patterns of densely graded aggregates, was applied to the study of ballast materials, that is, open-graded aggregates. The resilient modulus has been defined as the deviator stress (vertical minus confining pressure) divided by the recoverable portion of the axial strain (deflection) in a triaxial test [3, p. 10]. It is a measure of deformability. In a railroad ballast section the resilient modulus would, by analogy, be the vertical load divided by the amount of deflection recovery after a wheel load has been removed.

Tests were made with a representative variety of ballast materials—limestone, granitic gneiss, blast furnace slag, basalt, gravel, prepared gravel—with gradations corresponding to the AREA No. 4 and No. 5 ballasts and one defined as "well graded." A deviator stress of 45 psi and a confining pressure of 15 psi were used as representative of the stress conditions 2 in. below the bottom of a tie.

Thompson applied a widely used equation that accounts for the stress-dependent action of granular materials in the regression analysis of a series of triaxial tests [3, p. 17]:

$$E_r = K\theta^n \tag{21.3}$$

where E_r = resilient modulus
θ = the first stress invariant = the sum of the triaxial pressures
K, n = constants of intercepts and slopes derived from a log-log plot of the tests data.

The empirical nature of the basic data suggests caution in the use of such an equation, but it does give some indication of how the need to resurface varies.

Note that higher traffic densities are usually combined with better grades of ballast and standards of maintenance. Lengthened cycles not only reduce maintenance expense but increase traffic capacity by reducing train delays due to maintenance-related slow orders. The method of restoring surface and line—by surfacing, ballast cleaning, undercutting, complete renewal—should be based on an economic evaluation of alternative procedures.

21. Dirty Ballast

Dirt in ballast destroys its drainage, sterility, resilience, and stability. Water accumulates and muddy, pumping track ensues (Figure 21.15). Where the accumulated dirt is of cementing quality, a hard, impermeable, uneven mass is formed within the ballast section.

Dirt can accumulate from three principal sources:

1. By subgrade intrusion, where particles from a weak or overstressed subgrade are forced upward into the ballast (or the ballast is forced into the subgrade).
2. By internal abrasion and weathering processes that crumble and powder the ballast particles.

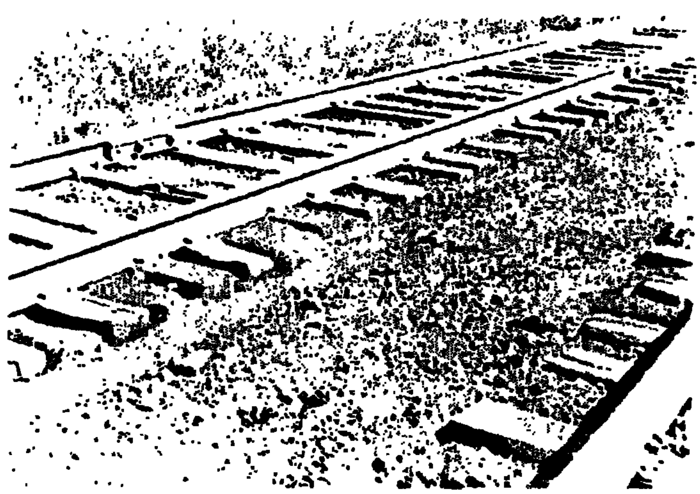

Figure 21.15. Dirty ballast and poorly drain track (Armco Drainage and Metal Products, Inc., Middletown, Ohio).

3. By external intrusion—wind-blown dust from newly plowed fields or sandy areas, droppings from cars of coal, grain or other granulars, sand from locomotive sanders (often ground to a powder between wheel and rail), and so on (sparks from steam locomotive exhausts, a one-time common source, are now nonexistent). The overflow from storm-filled ditches may deposit sediment in the ballast.

Subgrade intrusion occurs most frequently in poorly constructed or maintained branch lines and yards. Subgrade intrusion can occur on previously stable branch lines when high-tonnage cars are introduced. Too shallow a ballast section can permit subgrade intrusion. Internal degradation and external sources are, however, the usual causes of main line ballast fouling.

22. Cleaning and Rehabilitation

Dirty ballast must be cleaned to restore its desired qualities. Only the high-grade ballasts can be cleaned—crushed stone, crushed slag, and, in some instances, prepared gravels. For low-grade ballasts plowing or disking of the shoulders at the tie ends may have some beneficial effects, but the usual treatment is additional ballast and track raise or complete renewal.

A variety of cleaning procedures are in use, depending on the source and extent of fouling, the importance of the line, traffic density, and overall economic costs. Hay, Baugher, and Reinschmidt (1977) and Lynch (1978) (see Suggested Readings) present detailed analyses of the relative costs of various procedures.

a. Shoulder Cleaning

Shoulder cleaning has been a traditional procedure. By cleaning the shoulders (or the intertrack space), mud "dams" formed at the tie ends are broken and drainage from within the ballast section is promoted.

At one time all ballast was hand cleaned, either by shaking on ballast forks or by throwing the forked-out ballast onto a screen. Hand cleaning has only a limited use today. It may be used through crossings and turnouts or at any point where excessive mud has accumulated but where an out-of-face cleaning is not required and when mechanical means are not available.

Machines to clean the shoulders and intertrack followed. These machines, self-propelled or winch or locomotive drawn, use a plow box that advances through the ballast, forcing the material onto a conveyor belt and upward onto vibrating screens. The clean ballast is returned to the track. Dirt from beneath the screens is wasted by conveyor to cars

TRACK GEOTECHNOLOGY
and
SUBSTRUCTURE MANAGEMENT

Ernest T. Selig

Professor of Civil Engineering
University of Massachusetts
Amherst, Massachusetts, U.S.A.

and

John M. Waters

Railway Geotechnical Consultant
Derby, England

Table 2.3 Typical sleeper dimensions				
Location	Material	Width (mm)	Length (mm)	Spacing (mm)
Australia	Wood	210-260	2000-2743	610-760
	Concrete			600-685
China	Wood	190-220	2500	543-568
	Concrete	240-290	2500	568
Europe	Wood	250	2600	630-700
	Concrete	250-300	2300-2600	692
North America	Wood	229	2590	495
	Concrete	286	2629	610
South Africa	Wood	250	2100	700
	Concrete	203-254	2057	700
		230-300	2200	600

2.2. Ballast

Ballast is the select crushed granular material placed as the top layer of the substructure in which the sleepers are embedded.

Traditionally, angular, crushed, hard stones and rocks, uniformly graded, free of dust and dirt, and not prone to cementing action have been considered good ballast materials. However, at present no universal agreement exists concerning the proper specifications for the ballast material index characteristics such as size, shape, hardness, abrasion resistance, and composition that will provide the best track performance. This is a complex subject that is still being researched. Availability and economic considerations have been the prime factors considered in the selection of ballast materials. Thus, a wide variety of materials have been used for ballast such as crushed granite, basalt, limestone, slag and gravel.

Ballast performs many functions. The most important are:

1) Resist vertical (including uplift), lateral and longitudinal forces applied to the sleepers to retain track in its required position.

2) Provide some of the resiliency and energy absorption for the track.

3) Provide large voids for storage of fouling material in the ballast, and movement of particles through the ballast.

4) Facilitate maintenance surfacing and lining operations (to adjust track geometry) by the ability to rearrange ballast particles with tamping.

5) Provide immediate drainage of water falling onto the track.

6) Reduce pressures from the sleeper bearing area to acceptable stress levels for the underlying material.

Note that although the average stress will be reduced by increasing the ballast layer thickness, high contact stresses from the ballast particles will require durable material in the layer supporting the ballast.

Other functions are:

7) Alleviate frost problems by not being frost susceptible and by providing an insulating layer to protect the underlying layers.

8) Inhibit vegetation growth by providing a cover layer that is not suitable for vegetation.

9) Absorb airborne noise.

10) Provide adequate electrical resistance between rails.

11) Facilitate redesign/reconstruction of track.

As shown in Fig. 2.1 ballast may be subdivided into the following four zones:

1) Crib -- material between the sleepers.

2) Shoulder -- material beyond the sleeper ends down to the bottom of the ballast layer.

3) Top ballast -- upper portion of supporting ballast layer which is disturbed by tamping.

4) Bottom ballast -- lower portion of supporting ballast layer which is not disturbed by tamping and which generally is the more fouled portion.

In addition the term boxing may be used to designate all the ballast around the sleeper which is above the bottom of the sleeper, i.e., the upper shoulders and the cribs.

The mechanical properties of ballast result from a combination of the physical properties of the individual ballast material and its in-situ (i.e., in-place) physical state. Physical state can be defined by the in-place density, while the physical properties of the material can be described by various indices such as particle size, shape, angularity, hardness, surface texture and durability. The in-place unit weight of ballast is a result of compaction processes. The initial unit weight is usually created by maintenance tamping, together with mechanical compaction means discussed in Chapter 14, if used. Subsequent compaction results from train traffic combined with environmental factors.

In service the ballast gradation changes as a result of: 1) mechanical particle degradation during construction and maintenance work and under traffic loading, 2) chemical and mechanical weathering degradation from environmental changes, and 3) migration of fine particles from the surface and the underlying layers. Thus the ballast becomes fouled and loses its open-graded characteristics so that the ability of ballast to perform its important functions decreases and ultimately may be lost.

8.4.2.2 Results

An average percent by weight of the fouling components for each of the 5 fouling categories in Table 8.2 was determined for each site. The result is shown in Fig. 8.33. By far the most important source of fouling was ballast breakdown. Next, but a much smaller contributor, is infiltration of particles from granular layers beneath the ballast. These were generally old road bed layers on which new ballast was placed. Surface infiltration sources were third. Subgrade infiltration was an uncommon source.

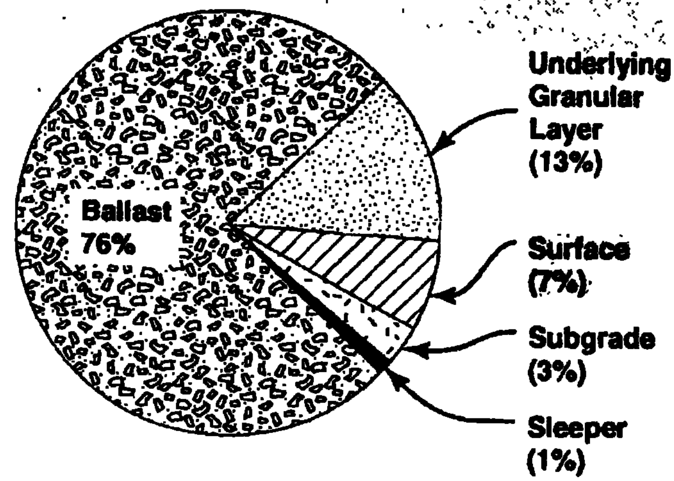

Fig. 8.33 Sources of ballast fouling for all sites combined

Although track subgrade was expected by many railroaders to be a major source of fouling, the results of this study indicate that it may be only a minor source. Clearly, the study shows that the presence of mud in the ballast does not indicate the existence of a subgrade fouling source. In fact, assuming that the mud is not from the subgrade is far more likely to be correct where a suitable subballast layer exists.. In general a combination of sources of fouling may be expected at individual locations, the mix depending on site specific conditions. The interpretation in any one case requires a proper subsurface investigation, since the clues cannot be obtained from surface inspection alone. However, a review of the fouling mechanisms described here will provide the basis for an accurate interpretation of the cause of fouling in most cases, without the need for the detailed laboratory investigation used in this research.

8.4.3. European Experience with Fouling

In Germany the main source of finer components is thought to be from the surface (category II) for two reasons (Ref. 8.16). First, a separation layer is required below the ballast to limit subgrade intrusion. Second, cleaned ballast removed from the track still has large particles with just worn corners.

Fouling from the subgrade (category V) results from overstressing at the ballast-subgrade contact points. The softening effect of water aggravates this situation and results in formation of a slurry. In the absence of a suitable separation layer, this slurry will pump up to the surface of the ballast to produce a 'pumping' failure. One of the difficult practical problems with drainage to prevent water accumulation is that the subgrade tends to settle most under the rails. This causes impermeable depressions which trap water that can produce subgrade softening, and lead to more settlement. This is a self-perpetuating

Ballast/sleeper attrition caused by ballast slurry can be prevented by using ballast material that is highly resistant to attrition. For this reason British Railways specify a maximum wet attrition value from the Deval test (Chapter 7) of 4%.

Ballast/sleeper attrition can be cured by ballast cleaning and/or ballast renewal using ballast that conforms to specification, particularly with respect to resistance to wet attrition. Good ballast drainage is also required.

8.4.6. Effect of Fouling

The effect of ballast fouling is to prevent the ballast from fulfilling its functions as described in Chapter 2. The specific effect depends on the amount and the character of the fouling material.

Sand- and fine-gravel-size fouling particles will increase the shear strength and stiffness of the ballast which adds to the stability and resistance to plastic strain as long as the coarse ballast particles still form the ballast skeleton. Frost protection will also be increased. However, void storage space and resiliency are reduced. Also surfacing and lining operations will become increasingly more difficult as the ballast voids become filled. Drainage will gradually decrease, but may remain adequate until the majority of the voids are filled. Segregation of particle sizes will occur during tamping, and when the voids become nearly filled, tamping will produce a looser ballast structure which will result in increased rate of settlement under further traffic. In general, a high degree of fouling from coarse sand and gravel particles will not cause significantly increased maintenance costs. Also the ballast can be readily cleaned.

The loss of performance mainly occurs when the fouling materials contain silt- and clay-size particles (fines). The quantity of these particles that will cause severe problems depends on the amount and size of the coarse-fouling components since these coarser particles reduce the void space, make the void sizes smaller, and combine with the fines to form an abrasive slurry. Clay particles alone will not form an abrasive slurry, but silt particles will. Both types of particles impede drainage and hence will increase the possibility of significant ballast deterioration, since water is a critical ingredient for severe ballast maintenance problems. The most important examples are: 1) hydraulic erosion, 2) subgrade attrition, and 3) loss of stability through particle lubrication. Ultimately when the degree of fouling with fines is high enough, the fines will control the ballast behavior and satisfactory geometry control will be impossible. As the degree of fouling with fines develops, tamping will become less effective in several ways: 1) when the fouling material becomes dry the ballast will be difficult to penetrate and rearrange, and the rearranged particles will be left in a looser state, and 2) when the ballast becomes wet, the particles' contacts will be coated with fines, lubricating them and the ballast will have a weakened structure after tamping. Maintenance will then be further increased because screening the ballast will be unsatisfactory, especially for clay fines, so that 100% replacement of the ballast may be necessary.

CERTIFICATE OF SERVICE

I hereby certify that on this date I caused to be served a copy of the foregoing Rebuttal Comments of the United States Department of Transportation via either e-mail or first-class mail, postage prepaid, on the all Parties of Record in STB Finance Docket No. 35305.

Paul Samuel Smith

Paul Samuel Smith
Senior Trial Attorney
U.S. Department of Transportation

June 4, 2010